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A Machine for Performance Tests of Anti-Friction Bearing Greases

By Paul G. Exline and S. A. Flesher

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Introduction

The extreme difficulty of evaluating anti-friction bearing greases in service is well known. The service performance of the grease depends upon three classes of variables; 1, the properties of the grease; 2, the operating variables and 3, the mechanical variables such as fit, clearance, surface finish, etc. The grease manufacturer usually can obtain little information on either of the latter two while even the user himself rarely has information on the third group.

Routine specification tests of greases are not capable of providing information on which to base predictions of performance in field service. There is thus a great need for test machines and procedures which will permit a more accurate evaluation of the grease by the manufacturer. This paper describes a machine which has been used in an attempt to secure such an evaluation.

The ideal grease evaluation machine would be one by which the grease could be subjected to a wide range of operating conditions under close control. The tests should be completed in a reasonably short length of time and repeat tests on the same grease should agree closely. Finally, the correlation between machine results and service performance should be good. We are still far from this ideal, but our experience with this machine has enabled us to see some of the pitfalls and has pointed out several promising points of attack.

Apparatus

The grease evaluation machine consists essentially of a device for rotating ball bearings, packed with the test grease, at constant speed, load and temperature. The bearings are mounted on stationary, parallel spindles and the outer races are rotated by steel wheels mounted thereon.

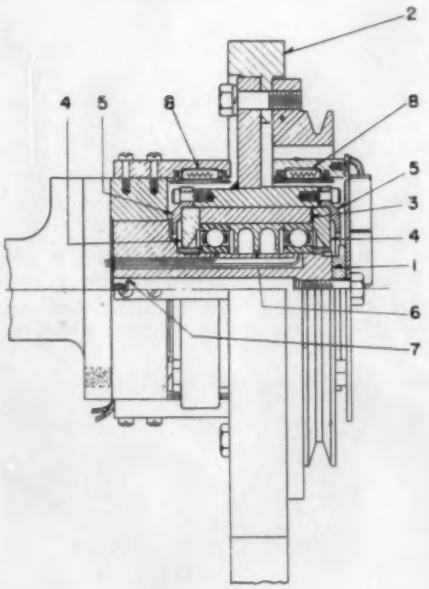

Fig. 1

Detail of Bearing Mountings in Wheel

A diagram of the bearing mounting is shown in Fig. 1. Two ball bearings are placed on the spindle 1 with a light press fit. The flat rimmed wheel 2 has a long hub which contains a cylindrical spacer 3 into which the outer races of the bearings are pressed. The bearings are confined in the hub by two seal plates 4 which in turn are forced inward by the two end plates 5. A thin aluminum gasket is placed between each bearing outer ring and the adjacent seal plate. These gaskets are 0.005 in. thick and wide enough to cover the face of the outer ring. They are used as seals to prevent loss of oil from the grease by leakage. The bearings are separated a distance of 2 1-4 in. by a deeply grooved separator 6. The purpose of the grooves is to prevent migration of grease from one bearing to another in order to permit use of different grease samples in each bearing. A cartridge heater 7 is placed in an axial hole drilled in the spindle. Two circular heaters 8 are mounted around each end of the hub to provide additional temperature control. The rear heater is supported by arms from the spindle base and the front heater from a plate clamped to the end of the spindle. Each of the three heaters has independent voltage control for adjusting the input. Bearing temperatures are measured by thermocouples placed with their junctions adjacent to the inner race of each bearing. The method of introducing these thermocouples is shown in the vertical plane in

CLINTON C. PECU

Clinton C. Pecu, well known in the grease industry, passed to his eternal rest Friday, August 10. "Clint" Pecu served some 42 years in the lubrication field in the steel industry.

Born in Vermont, he came to Buffalo in his early youth and spent most of his life at the Lackawanna Plant of the Bethlehem Steel Company.

Fig. 1, although in the machine they are actually in the horizontal plane, 90 deg. from the direction of loading.

Two of these wheel units are mounted in each machine as shown in Fig. 2 and are enclosed in an insulated housing. A pulley attached to the upper wheel is driven at 750 r.p.m. by a motor mounted outside the housing. The spindle of the lower wheel is attached to one end of a compound lever system so that it may be forced against the upper wheel and driven by contact on the smooth rim surfaces. In the photograph the weight 1 is suspended from one end of the lever system indicated by the arrows 2. This is counterbalanced so that with no weight on the pan, the lower wheel spindle will remain in a horizontal position when assembled for a test run. The upper spindle is mounted on a bar which can be adjusted by the two screws shown projecting from the top of the machine. This makes it possible to adjust the contact after load has been applied so that the force is transmitted uniformly across the width of the wheels. Once the adjustment has been made, the upper spindle support is located in position for the remainder of the test. The lever ratio is 100:1 and most of the test work has been carried out with a load of 1000 lb. per bearing, requiring a 20 lb. weight on the pan.

A sensitive thermostat is mounted in the housing and controls the bearing temperatures to several degrees Fahrenheit. Bearing temperatures are recorded by means of a multipoint recording potentiometer which not only gives a constant indication of the accuracy of control, but also indicates failure by a temperature rise.

Fig. 3 shows the parts in greater detail, the lower wheel having been removed to expose the spindle and the lower rear ring heaters. In this view, 1 is an oil line from a drop feed oiler which maintains a film of oil on the rims during the test, 2 is the sensitive element of thermoregulator and 3 shows the location of the bearing thermocouples.

BEARINGS

The bearings are SKF No. 210 deep grooved ball bearings, 50 mm. I.D. by 90 mm. O.D., containing ten 1-2 in. balls. It has been found preferable to use bearings obtained from a single manufacturer in order to eliminate manufacturing variables. The bearings themselves must be selected so that when mounted in the machine they will all have adequate internal clearance. The variables involved in this selection are hub diameter, which varies from wheel to wheel; the running clearance of the unmounted bearing and to a lesser extent the outside diameter of the bearing. In order to be able to make the proper bearing selection, it is necessary to have available a fairly large stock of bearings.

The internal bearing clearance is estimated from the "end play" or lateral freedom of the inner race when the outer race is fixed. This is measured by a dial indicator mounted on a jig which is supported by three legs resting on the end of the hub containing the bearing. The indicator spindle then touches a point on the end of the inner race of the bearing. The inner race is pulled firmly against the outer race at a point opposite the indicator. While held in this position the side of the race under the indicator is moved up and down. With no running clearance the dial indicator will show movement, but it will be small and proportional to the force applied. With clearance present the race will move freely over a short distance. If this free movement is less than 0.004 in. or 0.005 in., the bearing is too tight and should not be used. Values larger than this have no apparent effect on the results.

After selection of the proper bearing, it must be cleaned to remove all traces of the original grease. Cleaning is done by rinsing in naphtha and blowing with an air jet repeated several times. If the ball and races do not appear mirror clean after this treatment the bearing is then rinsed in acetone followed by application of the air jet. The air jet is used to remove the solvent, containing a small amount of grease, before it can evaporate on the surfaces.

The amount of grease placed in the bearing is determined by weighing the bearing before and after its application. The grease is placed in the bearing by a narrow bakelite spatula. It is spread uniformly around the bearing with as much as possible placed on the races themselves.

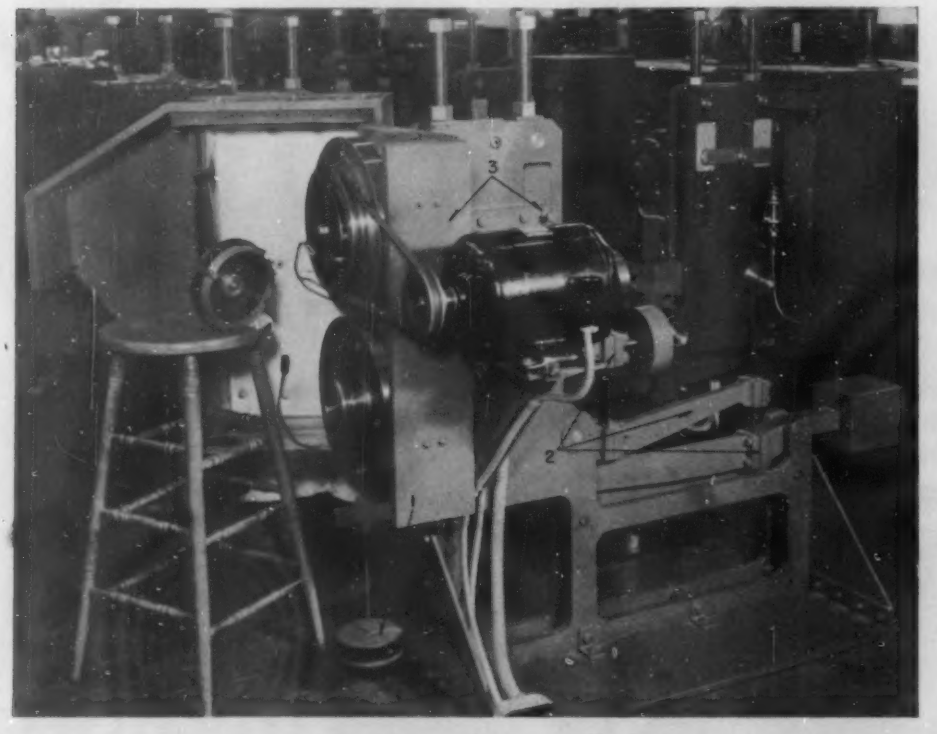

Fig. 2 Grease Evaluation Machine

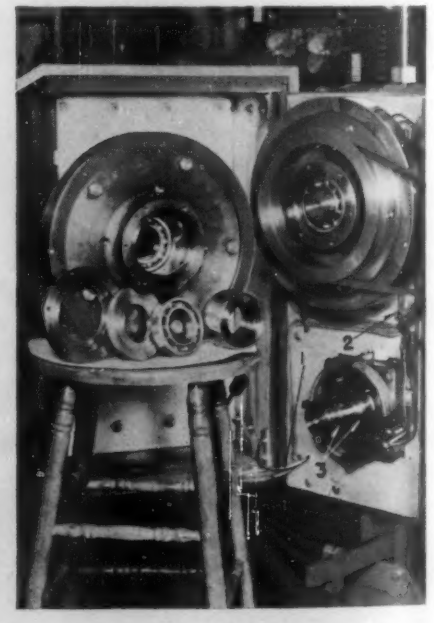

Fig. 3
Grease Evaluation Machine Showing Assembly Parts

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The charged bearings are installed in the wheels, one at each end of the hub with the separator between, by means of a press. Under these circumstances, the bearings project a trifle out of the hub so that the end plates, upon being fastened by means of screws, contact the outer races of the bearings rendering the entire assembly secure in the wheels. The wheels are then pushed onto the spindles, previously very slightly oiled, and the outer heater rings screwed to the ends of the spindles. With proper adjustment of the loading screws and heater controls, the machine is ready for its run.

At periodic intervals, whose length is determined by the temperature and the grease condition, the machine is stopped and the wheels removed for inspection of the bearings and the grease. The bearings themselves are not removed from the wheels during this examination. The condition of the grease and bearing are noted as well as the torque necessary to rotate the inner race by hand.

A test may be terminated for one or more of four reasons:

1. A rise of the indicated temperature amounting to more than 15 F. above the control temperature.
2. Dry race paths.
3. At the end of a predetermined time.
4. Appearance of pits in the balls or races.

ASPECTS OBSERVED AND STUDIED

At the periodic inspections as well as at the termination of the test, grease conditions are carefully observed and noted. Also a watch is kept for signs of bearing damage. It is obviously not sufficient to wait merely for some outward symptom such as temperature rise to draw conclusions regarding the merits of a grease. All aspects that may cast some light on the lubricating deficiencies or deterioration of the grease should be studied during the run. If one is to make a wise choice of lubricant in a given operation, he must know as far as possible the behavior of that lubricant during its term of service in that situation.

Darkening of a grease is one of the first signs of oxidation. With this usually comes an increase in viscosity, often complicated by separation and melting at high temperatures. Even though it is a grease whose melting point is above the operating temperature and which channels nicely at first, it will probably become quite fluent after some running. All these changes should be noted from time to time. The conditions when the machine is stopped and cooled are extremely important. The torque at high temperature is usually low, but after cooling, especially if the grease is pooled at the bottom, it may be dangerously high. On the other hand, if the grease consistency is found to be satisfactory throughout the test, it is very important to observe the situation inside the bearing. The race paths may be starved or gummed up. The amount and condition of the lubricant should be noted and the bearing felt for torque and smoothness. If the bearing is found damaged, the type of damage—discoloration, scaling, pitting, etc.—should be recorded, and correlated, if possible, with grease conditions.

Some examples of notes made during tests will serve to illustrate the points enumerated. Table I shows three tests which are typical, and also contrasting. The differences were due to differences in greases as all three were run under like conditions. These examples were chosen not only to show the adopted procedure but to illustrate the absolute need for periodic inspections in arriving at a reliable appraisal of a grease. Each of the three greases represented reveals some desirable characteristics. Each one also shows some weakness, but little of this information would be obtainable from an uninterrupted run to the end. Too often a grease is recommended and chosen in service on the basis of certain desirable characteristics while important characteristics which show up only in operation remain unknown and unconsidered. The procedure given in this paper tends to minimize this discrepancy.

In Sample No. 1 the fluency which was probably due to separation, would obviously be bad in certain applications. Before the end of the test the situation changed into a happy one in which the bulk of the grease remained channelled and firmly fixed, and "bled" a thin oil or grease to the race paths; and considering the high temperature, this situation was well sustained from the standpoint of time. However, for a heavy load at high temperature this lubrication might be too thin. The one in Sample No. 2 could be better, but in this one there is a dangerous point to note. During a certain stage of its life, when the machine was stopped and cooled the grease pooled and thickened so that it was almost impossible to move the inner race by hand. With such a starting torque in certain machines it would be impossible to restart, or ruinous to do so, without first reheating. The important observations to make in Sample No. 3 are that while the lubrication requirements were nicely met for a fair period of time, the lubrication gave out in the races long before the grease outside reached a bad state of deterioration.

CRITERION OF GREASE FAILURE

The criterion of grease failure is lack of lubrication manifested either by a temperature rise or by dry bearing races.

When failure is associated with a temperature rise of the bearing the change of temperature is usually quite rapid and is accompanied by a shrill screeching as if the bearing were wearing out. Detection of failure of this type involves no difficulty.

The indication of a dry bearing is sometimes troublesome because the bearing may run dry for some time with no outward symptoms of dryness. There is probably some protective coating in such cases, but the bearing is not lubricated in the ordinary sense.

It has been observed in scores of such instances that temperature rise and rapid wear may set in at any moment, or the test may continue for hours or even weeks depending on the operating temperature. The effect is apparently "triggered" by local action between the balls and races or

TABLE I

Examples of Notes Taken During Tests
Load—1000 lb. R.P.M.—750
Temperature—275 F.
Amount of Grease Charge—15 Grams

TEST EXAMPLE No. 1

185 hours—(hot) — Black. Almost all fluent. Low viscosity. Low torque. Races flooded. (cooled). Same.

350 hours—(hot)—All fluent. No other change.
(cooled)—Medium or low viscosity.

519 hours—(hot)—Channelled. Races well lubricated.
(cooled)—Gummy, but good in races. Moderately low torque.

667 hours—(hot)—No change.
(cooled)—Very gummy, but very good in races. Low torque.

764 hours—(hot)—No change.
(cooled)—Very gummy. Some hard gum. Races well lubricated with thin oil or grease. Test terminated for examination and further reference. Bearing apparently undamaged.

TEST EXAMPLE No. 2

192 hours—(hot)—Almost black. Mostly channelled, but appears to have been fluent. Low torque. Races well lubricated.
(cooled) — Lightly gummy. Moderately high torque.

425 hours—(hot) — Black. Semi-fluent. Low torque.
(cooled) — Pretty gummy. Very high torque.

542 hours—(hot)—Channelled. Appreciable amount in races. Medium torque.
(cooled) — Very gummy all around. Dangerously high torque.

659 hours—(hot)—Slight amount in races. Low torque.
(cooled)—Hard gum. Very viscous in races. Moderately high torque.

758 hours—(cooled) — Races dry. Very hard gum near races. Hard gum away. Approximate time to grease failure, 758 hours. Bearing slightly discolored.

TEST EXAMPLE No. 3

161 hours—(hot)—Dark brown, some very. Very well channelled. Well lubricated. Low torque.
(cooled)—Rather high consistency, but little different from new. Softer in races. Moderately low torque.

349 hours—(hot)—Dull brown to very dark. Little in races.
(cooled)—Harder. Low torque.

518 hours—(hot)—Very dark brown to black. Little in races.
(cooled)—Very gummy near races. Pasty in races, causing some binding. Torque about medium, but irregular.

608 hours—(cooled)—Races dry and crusted. Very gummy near races. Rest gummy and a good deal hardened, but would lubricate well at high temperature if it were in races. Approximate time to grease failure, 608 hours. Bearing slightly discolored.

TABLE II

Grease Test Results Showing Comparisons of Failure Times in Duplicate Tests
Load—1000 lb. r.p.m.—750
Temperature—330 F.
Amount of Charge—15 grams

Grease	*Test No.*	*Approx. Time to Failure* Grease 1st Test	2nd Test
4	672	63	63
24	664	74	74
11	620	96	114
23	662	105	105
14	812	115	115
30	814	130	115
2	674	112	137
1	676	125	125
32	638	126	126
31	636	132	132
8	750	144	151
5	700	148	159
20	690	143	165
10	748	144	164
17	688	134	175
12	622	150	162
3	670	160	160
13	686	145	175
9	728	162	162
29	630	154	173
22	738	174	162
26	692	165	176
28	628	173	173
25	612	154	186
6	698	181	159
27	614	186	176
16	648	186	186
18	712	188	200
19	710	174	212
15	646	198	210
7	730	252	238
21	740	248	248

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TABLE III

Grease Test Results Showing Comparisons of Grease Conditions in Duplicate Tests
Load—1000 lb. r.p.m.—750
Temperature—275 F.
Amount of Charge—15 grams

Grease	*Test No.*	*Approx. Time to Failure* Grease 1st Test	2nd Test	*Grease Condition* 1st Test	2nd Test
4	684	246	246	E	EF
24	No test				
11	632	654	563	DE & E	DE & E
23	No test				
14	777	768	768	E	E
30	821	771*	771*	DE	D & DE
2	668	758*	758*	E	DE
1	666	758*	758	DE & E	E & EF
32	624	764*	764*	E	DE & E
31	618	586*	586*	DE	DE
8	752	603	603	E	E
5	702	763*	763*	DE	DE to E
20	696	768*	768*	DE	DE & E
10	754	504	504	E	E
17	682	762*	762*	E	E
12	634	754*	608	D & DE	D & DE
3	680	767*	767*	DE	DE
13	678	767*	600	D & DE	D & DE
9	726	667	767*	EF	D
29	616	753*	753*	DE	DE
22	744	764	764*	E	DE
26	694	768*	768*	D & DE	D & DE
28	608	768*	768*	E	DE & E
25	610	588*	588*	DE	DE
6	704	763*	763*	D to DE	DE
27	606	768*	768*	DE	DE
16	656	759*	759*	DE	E
18	716	766*	766*	E	E
19	718	766*	712	E	DE to E
15	654	759*	759*	D to E	DC & D
7	734	651	651	E	E
21	No test				

* Test terminated before grease failure.

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TABLE IV

Life-Test Comparison Between Sodium and Calcium Base Greases
Load—1500 lb. r.p.m.—750
Temperature—250 F.
Amount of Grease Charge—7 grams

Base	*Grease*	*No. of Tests*	*Average Hours to Failure*
Sodium	A	3	1120
Sodium	B	2	1020
Sodium	C	1	680
Sodium	D	1	620
Calcium	E	3	188
Calcium	F	2	102
Calcium	G	2	74

between the balls and separator, following which it spreads rapidly throughout the bearing. Within an hour the bearing is in a bad state of ruin, often called "burnt up."

It has also been observed that if any trace of lubricant that still retained any fluency was present on the race paths, failure never occurred immediately. In many cases the runs continued for a long time with little or no noticeable change in the races, especially if the film, even though thin to the point of invisibility, was not gummed up. These observations indicate that the race paths must be quite dry before any appreciable temperature rise or wear begins.

The final determination of dryness is sometimes difficult. It requires experience and involves the use of the three senses of sight, hearing and touch. As an example, many times no lubricant has been visible on the race paths, but the bearing is quiet and it feels padded or cushioned when pressure is applied by hand and the bearing rotated slowly. This behavior gives way to one of harshness as the races become dry. The bearing may hiss or screech as it is rotated, the race paths become irregularly spotted or glazed, or look dulled though not necessarily damaged. When rotated by hand it feels as though the balls were rolling over tiny obstructions. This transition usually comes with sufficient suddenness that one can fix the time with reasonable accuracy if the inspections are well timed.

Occasionally relatively large pieces of metal will chip or spall from the surfaces of the balls or races. This is not necessarily associated with grease failure. In fact, it occurs only in the presence of grease. Its occurrence is easily detected by the noise or roar of the balls rolling over the pits.

It is important to differentiate between such a failure of the bearing and a true failure of the grease. A well lubricated bearing will eventually fail through pitting if run long enough under a heavy load. The number of bearings failing in a given time will follow a probability curve and in testing greases the conditions must be chosen to secure a low probability of bearing failure.

In some tests when the presence of pits had made itself heard the inner ring was rotated on the spindle to place the pits on the unloaded side and the test continued. This still left the particles of metal in the grease yet the results show no great difference, on the average, in grease condition or grease-failure time between the pitted and unpitted bearings.

The opinion is expressed here that there are two separate problems involved: one concerning the endurance of the grease and the other the anti-pitting protection afforded by the grease. There is some evidence that this protection is a function of the oil viscosity and the soap content, but a discussion of these factors is outside the scope of this paper.

REPRODUCIBILITY

Table II lists the hours to failure for two tests on each of 32 different grease samples. These tests were run at a temperature of 330 F., a speed of 750 r.p.m. and a load of 1000 lb. per bearing. In all cases the initial grease charge was 15 grams. The test numbers given are for the first run, the duplicate run being given the next consecutive number. The greases are listed in the order of increasing time to failure, although the table is not intended to be used as a rating of the greases.

Failure was indicated by dryness of the races with three exceptions in which the indication was temperature rise of the bearing. The greatest percentage difference in times to failure was between tests Nos. 688 and 689. The average percentage deviation from the mean for all the tests was 4 per cent. Such a low value is due largely to the fact that the two tests were run simultaneously in the same wheel, the inspection periods coincide, and judgment of failure in one bearing undoubtedly influenced the judgment regarding the other bearing, particularly in critical cases.

At lower temperatures the running time increases enormously. In order to save time more reliance is generally placed on the notes taken during the periodic inspections and the tests discontinued before they are terminated by grease failure. Table III lists a group of tests on the same greases as Table II with all conditions the same except that the temperatures were 275 F. Those marked with an asterisk were discontinued shortly after 750 hours' running time. In this table the greases are listed in the same order as in Table II. It will be noted that in five of the six cases where failure occurred in both tests, the times were identical. This again is due partly to the fact that both tests were run simultaneously in the same wheel and the inspection periods coincided.

The letter symbols indicating the condition of the grease on the lands and separators were arbitrarily chosen early in the program and have the following somewhat loose meaning:

A. Like new	D. Gummy
B. Darker	E. Hard gum
C. Darker and more viscous	F. Powdered

When this rating was found to be inadequate, combinations of letters were used to indicate intermediate conditions. Although this is largely a subjective method of indicating condition, all ratings throughout the entire program have been made by the same operator (S. A. Flesher).

Six grease evaluation machines have been in nearly constant operation during the past four years. The tests reported in Table II were all carried out in one machine which was maintained at 330 F. Three of the remainder were maintained at 275 F. and were used in collecting the data shown in Table III.

It was thought desirable to find out what results would be obtained with these machines in tests on low-temperature greases run at a high temperature. Three such greases (calcium-soap base) were chosen and several tests run at 250 F. to grease failure. These are tabulated for comparison with results obtained under the same operating conditions on four sodium-base greases, which are greases recommended for high-temperature service.

CONCLUSION

The grease evaluation machines described have been designed and operated in an attempt to secure a method as objective as possible for evaluating greases. The achievement of this goal has been limited since the method largely depends on the skill and judgment of the operator. The machines have been of great value in indicating the influence of various changes in grease composition upon its performance.

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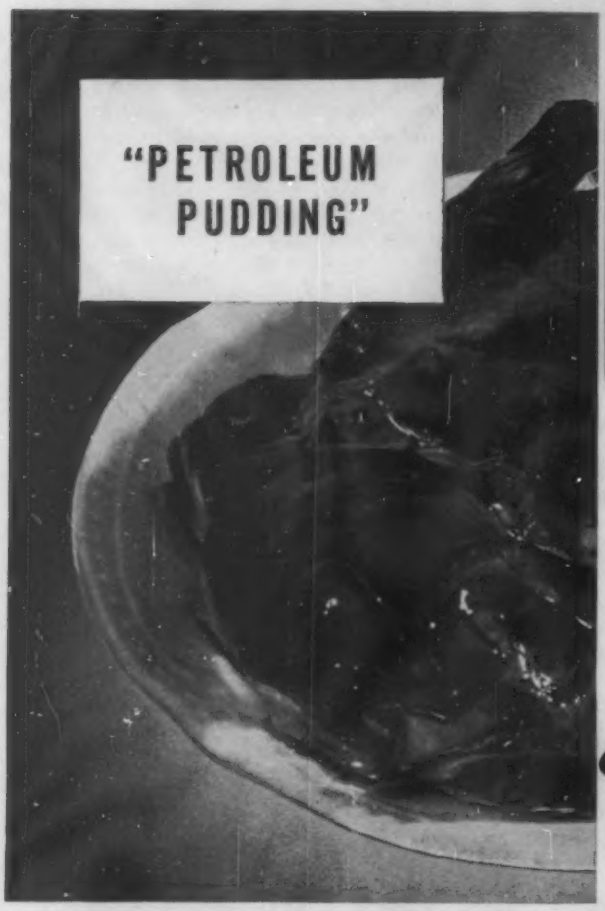

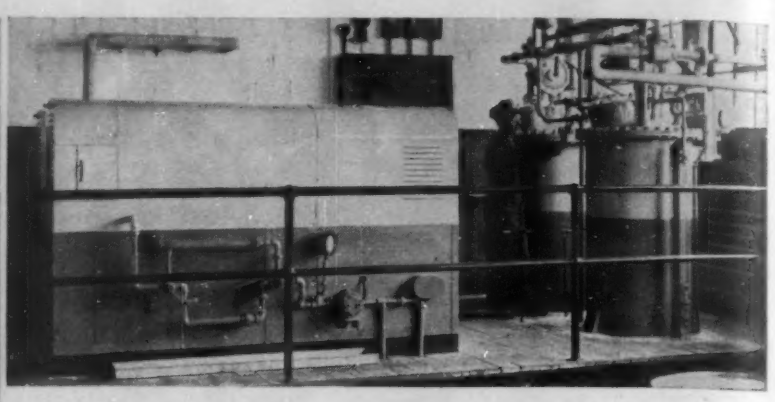

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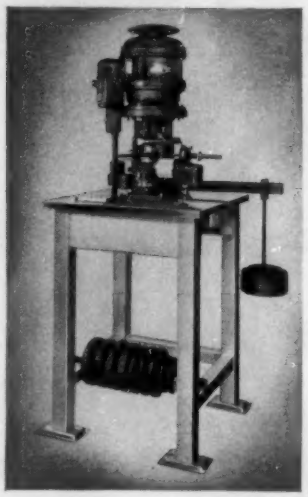

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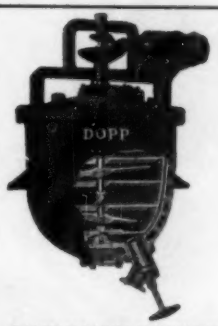

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